Identifying people at higher risk of melanoma across the UK: a primary care-based electronic survey

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Running title: Identifying people at higher risk of melanoma

What's already known about this topic?

- Programmes to identify people at higher risk of melanoma and offer them preventive advice about sun protection, skin awareness, early consultation or surveillance are of increasing interest to healthcare providers in the UK and internationally.
- Numerous models for predicting future risk of melanoma exist, with little difference between models suitable for self-assessment and those requiring a health care professional; none have been calibrated for the UK population.

What does this study add?

- Collecting data on the melanoma risk profile of the general population in UK primary care is both feasible and acceptable.
- This provides an opportunity for new methods of real-time risk assessment in primary care.
- Using the Williams model produces a distribution of risk in the population attending GP practices which allows identification of sub-groups at different levels of risk.
- As regional differences were small a single approach could be implemented.

SUMMARY

Background

Melanoma incidence is rising rapidly worldwide among Caucasian populations. Defining higher-risk populations using risk prediction models may help targeted screening and early detection approaches. We aimed to assess the feasibility of identifying people at higher risk of melanoma using the Williams self-assessed clinical risk estimation model in UK primary care.

Methods

We recruited participants from the waiting rooms of 22 general practices covering a total population of >240,000 in three UK regions: Eastern England, Northeast Scotland and North Wales. Participants completed an electronic questionnaire using tablet computers. The main outcome was the mean melanoma risk score using the Williams melanoma risk model.

Results

7,742 of 9,004 approached people completed the electronic questionnaire (86%). The mean melanoma risk score for the 7,566 eligible participants was 17.15 (SD 8.51), with small regional differences (lower in England compared with Scotland ($p = 0.001$) and Wales ($p < 0.0005$)), mainly due to greater freckling and childhood sunburn among Scottish and Welsh participants. After weighting to the age and gender distribution, different potential cut-offs would allow between 4% and 20% of the population to be identified as higher risk, and those groups would contain 30% and 60% respectively of those likely to develop melanoma.

Conclusions

Collecting data on the melanoma risk profile of the general population in UK primary care is both feasible and acceptable for patients in a general practice setting, and provides opportunities for new methods of real-time risk assessment and risk stratified cancer interventions.

Key words: Melanoma, risk assessment, primary care

INTRODUCTION

Melanoma is the leading cause of skin cancer deaths in the UK, with incidence rates having increased by 55% between 2000 and 2009 and continuing to rise (1, 2). Identifying people at higher risk of melanoma can help early diagnosis and prevention, and in turn mortality (3, 4). Screening programmes to identify those at higher risk of melanoma and offer them preventive advice about sun protection and skin awareness and early consultation or surveillance are, therefore, of increasing interest to policy and healthcare providers.

Currently mass-screening is not recommended in the UK because of difficulties in identifying the target population (5), plus concerns about the low incidence of melanoma and therefore the time and resources required to identify a relatively small number of people with the disease (6). Additionally, while the SCREEN project in northern Germany has suggested that population screening is feasible and may have an impact on diagnosis and 5 year mortality, it led to an increase in biopsies (7, 8), and there has been insufficient evidence for the cost-effectiveness of routine screening of the general population using a total body skin examination (9). Previous studies, however, suggest that selective, targeted screening might be more cost-effective as the cost falls dramatically when screening is targeted to higher risk populations, defined variously by age, family history or phenotypic characteristics (10-14). A stratified approach is currently recommended for Australian primary care physicians, advised to perform skin examinations every 3-12 months in people with multiple atypical or dysplastic naevi or a first-degree relative with melanoma (15).

The overall impact of stratified screening for melanoma, however, depends on easily and accurately identifying a high-risk group (16). This may be improved by the use of risk prediction models. Our recent systematic review identified 25 risk models for predicting future risk of melanoma (17). Twelve of

those are suitable for self-assessment (defined as not including any of the following factors: dysplastic or atypical naevi, actinic lentigines, total body naevus count, genetic analysis requiring samples, or specialised equipment such as dermoscopy or colorimetry). Many had performance measures comparable to those for other cancers, including breast cancer (18) and colon cancer (19), and there was little difference between those scores suitable for self-assessment and those requiring a health care professional. The review did not identify any risk models calibrated for the UK population and none were more than moderately predictive. Of those suitable for self-assessment, only one developed from a US case-control study by Williams *et al* (20) had been validated outside the development population. It is a self-assessed clinical risk estimation model not requiring full-body skin examination that, in a validation population, had an area under the receiver operator characteristic curve of 0.70 (95% C.I. 0.64 to 0.77) and was able to identify 15% of the population in whom 50% of melanomas would be expected to develop. The Williams score can therefore be used to determine population risk of melanoma and enable stratified screening based on individual risk. The aim of this study was to assess the feasibility of identifying people at higher risk of melanoma using the Williams self-assessed clinical risk estimation model, the 'Williams model' (20) in UK primary care.

METHODS

Study Population and Data Collection

Ethical approval was gained from the West Midlands Research Ethics Committee (13/WM/0405). Participants were recruited from general practices in Eastern England (n=10), Northeast Scotland (n=6) and North Wales (n=6) between February 2014 and March 2015. Patients and companions aged ≥20 years were approached in general practice waiting rooms by trained researchers at different times of day and different days of the week; posters were also placed in the waiting rooms to advertise the study. Those willing to take part were invited to complete an electronic questionnaire using tablet computers.

The gender and reason for not wishing to participate was recorded for each person choosing not to take part.

Tablet computer-administered electronic questionnaire

The electronic questionnaire consisted of two sections: the Williams model and additional demographic variables. The questions for the Williams model were phrased as originally reported (20) and included: gender, age, natural hair color at the age of 15, number of raised moles on both arms, density of freckles on both arms before the age of 20, number of severe sunburns up to the age of 18, and prior non-melanoma skin cancer (basal-cell cancer and squamous-cell cancer). Participants were also asked whether they had had melanoma. Age was collected in six age bands (20-34, 35-44, 45-54, 55-64. 65-74 and ≥75 years). The questions and possible responses for the other risk factors are shown in Box 1. Photographic images were included of raised moles and freckles alongside those questions to facilitate completion of the questionnaire by each participant independently. The demographic section included questions on ethnic group, education level, and employment status.

Statistical analyses

The risk score for each participant was calculated using the points scoring system developed by Williams *et al*. (Box 2) (20). We then computed the mean risk score and standard deviation for the entire sample and for each of the three regions separately, and compared the mean risk in each of the three regions using linear regression adjusting for the age and gender of participants. We proceeded to calculate the proportion of participants who would be identified as high risk using each of the four risk score cut-offs used by Williams *et al.* (25, 28, 30, and 34). We repeated this weighted to the age and gender distribution of the registered practice populations to obtain estimates of the proportion of the population who would be classified as high risk if the entire practice population had been questioned. To estimate the positive

predictive value (PPV) and negative predictive value (NPV) for each cut-off we assumed that the Williams model would perform equally in the UK population as in the published validation study. We used the sensitivity and specificity reported by Williams *et al*. for each of the four risk score cut-offs and the published national data for 2011 crude melanoma incidence to estimate 5 year PPVs and 5 year NPVs. All analyses were performed using STATA version 12.

RESULTS

General practices

The 10 Eastern England practices had between 4,229 and 20,279 registered patients and covered a total population of 112,651 patients; most were urban (n = 7). The six in Northeast Scotland were mostly rural or semi-rural (n = 5) with between 1,845 and 20,976 registered patients covering a total population of 68,010, and the six in North Wales were mostly urban or semi-urban (n = 5) with between 5,801 and 15,409 registered patients covering a total population of 60,096 (Table 1).

Participant recruitment

The total person-time spent recruiting was 1009 hours, with the time in each practice ranging from 15 to 93 hours and the mean time per participant ranging from 2.1 to 18.5 minutes (mean 8.2, SD 5.0 minutes). This variation was largely due to differences in patient flow within practices. Factors facilitating quicker recruitment included: larger practice size; a greater number of doctors in the practice at the time; larger waiting rooms with more space to approach patients; and longer waiting times for appointments. Conversely, recruitment was difficult at times when large numbers of patients were arriving for very short appointments, such as blood tests of flu vaccinations, as many were called in before they had time to complete the questionnaire. Overall, 9,004 people (3.7% of the registered population) were approached and 7,742 completed the electronic questionnaire (86%) (Figure 1). 275 people agreed to take part but

were called for their appointment before completing the electronic questionnaire (3%), and 1,063 people (12%) declined to participate. The total number recruited from the Eastern England practices was higher than in Northeast Scotland or North Wales (4,140 compared to 1,509 and 2,093 respectively) but acceptance rates were similar in all three regions (Eastern England 85.3%, Northeast Scotland 86.8%, North Wales 86.7%). Reasons for not wishing to participate varied: over half either provided no reason or indicated no interest in the study (*n* = 593, 55.8%) with other common reasons including poor English (*n* = 86, 8.1%), no time (*n* = 72, 6.8%), and not having glasses with them (*n* = 59, 5.6%).

Participants

We excluded 177 (2.3%) participants (Eastern England 101, Northeast Scotland 29, North Wales 47) who had a history of melanoma. 7,566 participants are therefore included in further analyses. Table 2 shows the details of these 7,566 participants by the three regions with comparison where possible to the total patients registered in the practices. The majority were white (British and others, 96.5%), reflecting the regional populations (21, 22). Our sample contained proportionately fewer male, and older, participants than that of registered patients in the practices. Most were retired (30.1%) or working full-time (35.9%), and education levels were similar to those in the 2011 Office of National Statistics, with over a quarter having an undergraduate degree (10.4%) or postgraduate degree or professional qualification (16.7%).

Distribution of melanoma risk factors and scores

Table 3 shows the mean risk score in each of the three regions and for the entire study population along with a breakdown of the proportion with each risk factor. The mean risk score for all 7,566 participants was 17.15 (Standard Deviation (SD) 8.51) and was similar in each of the three regions (Eastern England: mean 16.79, SD 8.47; Northeast Scotland: mean 17.87, SD 8.41; North Wales: mean 17.37, SD 8.60).

This difference in mean scores between Northeast Scotland and Eastern England of 1.10 (95% CI 0.59 to 1.61) reduced to 0.67 (95% CI 0.26 to 1.09, p = 0.001) after adjusting for age and gender; the corresponding difference between North Wales and Eastern England increased from 0.60 (95% CI 0.14 to 1.05) to 0.80 (95% CI 0.43 to 1.18, p < 0.0005) after adjusting for age and gender. These differences were mostly explained by increased density of freckles on both arms before the age of 20 and a greater number of severe sunburns aged 2-18 years reported by participants in both Northeast Scotland and North Wales; the difference between Northeast Scotland and North Wales was not significant ($p = 0.58$).

Figure 2 shows the distribution (unweighted) of melanoma risk scores in each of the three regions and the entire study population, overlaid with the four cut-off points used in the Williams model. Table 4 shows the percentage of the study participants above each of the four cut-off points used in the Williams model, along with the estimated percentage of the registered practice population at all the included practices (estimated by weighting to age and gender distribution of practice populations) above each cut-off. Estimated positive predictive and negative predictive values are also given for each cut-off in the three regions using the values for the relative risk, sensitivity and specificity reported in the Williams paper and assuming that the model is transferable to the UK population (20). These suggest that, for example, using the lowest cut-off of 25 would classify approximately 17.7% of the practice populations in Eastern England as higher risk. This group would contain approximately 61% of the people predicted to be diagnosed with a melanoma at any time in the future and approximately 3.1% of this group would be expected to develop melanoma in the following five years. These values are similar for Northeast Scotland and North Wales but a slightly greater proportion of the population would be classified as high risk in both regions than in Eastern England at all thresholds (Table 4).

DISCUSSION

To our knowledge this is the first study to use tablet computers to collect data specifically on risk of cancer in primary care. We have shown that collecting data on the risk profile of the general population in UK primary care is both feasible and acceptable. This provides an opportunity for new methods of real-time risk assessment in primary care for melanoma and for other cancers. We have also shown that using the Williams model (20) produces a distribution of risk in the population attending GP practices which allows identification of sub-groups at different levels of risk. Although this distribution varied slightly between the three regions of the UK included in this study, the differences were small and, from a policy perspective, suggest that a single risk stratifying approach could be implemented across the whole UK in the future.

The main strength of this study is the method of collecting data. Over 90% of patients approached while attending routine general practice agreed to take part, and we were able to easily recruit 7,742 participants from three regions across the UK with an average total researcher time per participant of less than 10 minutes. Furthermore, we were able to collect data from a large sample representing a general practice population of almost quarter of a million people, and drawn from three distinct regions across the UK.

This data collection method, however, has its limitations. First, the recruited sample is drawn from those attending general practice, so we acknowledge that we may not have accessed individuals who are reluctant to visit their doctors, and that some selective approaching of potential participants was inevitable. The older people and women will tend to be over-represented as they attend general practice more than younger people and men (23); women are also more likely to be in the practice accompanying young children or more elderly people. To account for this we repeated our analysis with our sample

weighted to the practice registered populations. This requires the assumption that the risk of developing melanoma in the patients not attending the practice is the same as those of the same age and gender who did attend the practice during the recruitment period. We think this assumption is reasonable as most primary care consultations are not related to melanoma or its risk factors. Our sample is also predominantly white (British and others) which limits the generalizability of our findings to other ethnic groups, many of whom would be at lower risk of melanoma. The ethnic distribution of our sample does, however, reflect the regional populations in the three areas where over 90% are white British, and are likely to be targeted in a risk stratified melanoma screening programme.

Other limitations include that this was a cross-sectional study with no follow-up. The absence of melanoma outcomes means we are unable to assess the performance of the Williams model in this UK population. The estimated 5-year PPVs and NPVs are therefore based on the sensitivity and specificity of the different risk score cut-off values reported from the original paper by Williams *et al* (20). We acknowledge that the model was self-validated on a fairly small dataset from Washington State, USA, where the cases were all white and aged between 35 and 74. The performance measures reported by Williams *et al* at the different thresholds are, therefore, estimates calculated from this sample not the whole population. The model has also not been calibrated for the UK population. The age-standardised incidence of melanoma is lower in the UK than in the USA (17.3/100,000 for England in 2011 (6), compared to 22.86/100,000 in the USA in 2011 (24)), so the sensitivity may be slightly higher and the specificity slightly lower due to spectrum effect. We also excluded patients with previous melanoma whilst national incidence data includes all new cases of melanoma. The Williams model does not contain some expected risk factors such as family history of skin cancer and skin colour. Our review found that family history was absent in many models: it was considered in 18 of the models but only remained in the final score in 6 (17). Finally, most of the questions were asking either about the past and so subject to

recall bias or required participants to count raised moles. However, the same biases would be true for the original Williams model which performed well in an external validation cohort and in this study we additionally included photographs of moles and freckles to help participants distinguish between them which, if anything, would be expected to improve the performance of the model.

Only one similar study has been conducted for melanoma risk (25), where patients at 16 English general practices completed a paper questionnaire based on a risk score developed by Mackie (26). While this is, therefore, the first study to use tablet computers to collect melanoma, or any other cancer-specific risk factor information, in general practice waiting rooms, tablet computers have been used in this setting previously. One collected general health risk information from patients attending an Aboriginal Community Controlled Health Service in Australia (27), and two UK vignette-based studies have recently investigated ethnic differences in preferences for prostate cancer investigation (28), and for investigation for possible lung, colorectal and pancreatic cancer (29): both had high (>70%) recruitment rates. This study therefore supports the increasing interest in making the most of the "waiting room wait", both for clinical practice and research. It also identifies a number of factors to be considered when recruiting participants from primary care waiting rooms. In particular, the need to consider the layout of the waiting room and patient flow through each practice and, where possible, select times when there are the more appointments with GPs and less for very short consultations such as blood tests or flu vaccinations. However, as we did in this study, it remains important to sample at different times during the day to provide the opportunity to recruit a range of patient groups. For example, working individuals may favour early and late appointments, older patients may favour appointments in the middle of the day, and parents with children may favour after school appointments.

This study also provides useful evidence for the planning and development of future screening and educational programmes in the UK for people at higher risk of melanoma. It shows that collecting information on risk factors in general practices across the UK is feasible and acceptable to patients, and that use of a melanoma risk model allows stratification of the population into different risk groups. The small differences in risk profiles between the three UK regions is also consistent with UK melanoma incidence rates which show only small and non-statistically significant differences (30) and suggests that a single approach could be introduced across the UK.

Identifying those at higher risk in this way, therefore, could allow screening, surveillance or education programmes to be targeted at those most likely to benefit, including specific advice and support via primary care. In particular, the risk stratification could be used to determine the interval for surveillance, with those at higher risk being recommended to have more frequent screening. This is of particular relevance to conditions like melanoma where the overall incidence is low but the benefits of prevention or identifying people with disease earlier are substantial. The low incidence means interventions at the whole population level have considerable implications in terms of health care costs to benefit only a small number for whom early detection could improve treatment options, reduce morbidity and mortality, and both physical and psychological consequences to the large numbers who are unlikely to ever develop the condition (31).

The proportion of the population in the higher risk group depends on the choice of risk cut-off point. As with all screening there is a trade-off between sensitivity and specificity. A cut- off with higher sensitivity will increase the proportion of those likely to go on to develop melanoma being identified as higher risk, but at the expense of a lower specificity and a larger proportion of the population classified as higher risk. Using the four cut-off points of the Williams model in this study would identify between

4% and 20% of the population as candidates for a targeted intervention, and those groups would contain between approximately 30% and 60% respectively, of those likely to develop melanoma. This is not dissimilar to the 8.7% of the population identified as "worryingly high risk" or "very increased risk" in the study by Jackson *et al* (25). While such strategies are likely to increase local referral rates and dermatology workload, and there is a UK shortage of dermatologists, a recent review suggests that melanoma early detection programmes might be cost-effective (14) if targeted at high-risk populations such as older men (32) or those with a family history of melanoma (12). It is likely that identifying higher-risk individuals using a risk score would be more cost-effective, but further studies are needed to confirm this and to determine the most cost effective intervals for surveillance amongst those at different levels of risk.

The finding that collecting risk information in waiting rooms in general practices across the UK using tablet computers was both feasible and acceptable to patients also has implications beyond screening for melanoma. In addition to completing risk assessment questionnaires, patients could also: identify consultation goals and enable doctors to better tailor appointments; be provided with educational material; and complete decision aids (33). The acceptability of a self-completed tool also suggests that similar approaches could be used more widely in settings outside the waiting room, such as in pharmacies or secondary care, as well as potentially via web based applications.

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REFERENCES

1. Linos E, Swetter SM, Cockburn MG, Colditz GA, Clarke CA. Increasing burden of melanoma in the United States. J Invest Dermatol. 2009 Jul;**129**(7):1666-74.

2. Arnold M, Holterhues C, Hollestein LM, et al. Trends in incidence and predictions of cutaneous melanoma across Europe up to 2015. J Eur Acad Dermatol Venereol. 2014 Sep;**28**(9):1170-8.

3. Abdel-Rahman M, Stockton D, Rachet B, Hakulinen T, Coleman MP. What if cancer survival in Britain were the same as in Europe: how many deaths are avoidable? Br J Cancer. 2009 Dec 3;**101 Suppl 2**:S115-24.

4. Neal RD, Tharmanathan P, France B, et al. Is increased time to diagnosis and treatment in symptomatic cancer associated with poorer outcomes? Systematic review. Br J Cancer. 2015;**112 Suppl**:S92-S107.

5. Melia J, Harland C, Moss S, Eiser JR, Pendry L. Feasibility of targeted early detection for melanoma: a population-based screening study. Br J Cancer. 2000;**82**(9):1605-9.

6. Cancer Research UK. Melanoma screening. Available from: http://www.cancerresearchuk.org/cancer-help/type/melanoma/about/melanoma-risks-and-causes. (Accessed 26/03/16).

7. Breitbart EW, Waldmann A, Nolte S, Capellaro M, Greinert R, Volkmer B, Katalinic A. Systematic skin cancer screening in Northern Germany. *J Am Acad Dermatol* 2012;**66**: 201–211, doi:10.1016/j.jaad.2010.11.016.

8. Waldmann A, Nolte S, Weinstock MA, Breitbart EW, Eisemann N, Geller AC, Greinert R, Volkmer B, Katalinic A. Skin cancer screening participation and impact on melanoma incidence in Germany--an observational study on incidence trends in regions with and without population-based screening. *Br J Cancer* 2012;**106**: 970–974, doi:10.1038/bjc.2012.22.

9. Wolff T, Tai E, Miller T. Screening for skin cancer: an update of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med* 2009;**150**: 194–198.

10. Girgis A, Campbell EM, Redman S, Sanson-Fisher RW. Screening for melanoma: a community survey of prevalence and predictors. Med J Aust. 1991;154(5):338-43.

11. Freedberg KA, Geller AC, Miller DR, Lew RA, Koh HK. Screening for malignant melanoma: A cost-effectiveness analysis. J Am Acad Dermatol. 1999;41(5 Pt 1):738-45.

12. Losina E, Walensky RP, Geller A, et al. Visual screening for malignant melanoma: a cost-effectiveness analysis. Arch Dermatol. 2007;143(1):21-8.

13. Gordon L, Youl PH, Elwood M, et al. Diagnosis and management costs of suspicious skin

lesions from a population-based melanoma screening programme. J Med Screen. 2007;14(2): 98-102.

14. Gordon LG, Rowell D. Health system costs of skin cancer and cost-effectiveness of skin cancer prevention and screening: a systematic review. Eur J Cancer Prev. 2014;**24**: 141–149.

15. Royal Australian College of General Practitioners . Guidelines for preventive activities in general practice 8th edition.

16. English DR, Armstrong BK. Identifying people at high risk of cutaneous malignant melanoma: Results from a case-control study in Western Australia. *Br Med J (Clin Res Ed)* 1988;**296**: 1285–1288.

17. Usher-Smith JA, Emery J, Kassianos AP, Walter FM. Risk Prediction Models for Melanoma: A Systematic Review. *Cancer Epidemiol Biomarkers Prev* 2014; **23**: 1450–1463.

18. Amir E, Freedman OC, Seruga B, Evans DG. Assessing women at high risk of breast cancer: a review of risk assessment models. *J Natl Cancer Inst* 2010;**102**: 680–691.

19. Usher-Smith JA, Walter FM, Emery J, Win AK, Griffin S. Risk prediction models for colorectal cancer: a systematic review. *Cancer Prev Res (Phila)*. 2016;9(1):13-26.

20. Williams LH, Shors AR, Barlow WE, Solomon C, White E. Identifying Persons at Highest Risk of Melanoma Using Self-Assessed Risk Factors. *J Clin Exp Dermatol Res*. 2011;2(6).

21. The Office of National Statistics Office of National Statistics 2011 Census Analysis, Local Area Analysis of Qualifications Across England and Wales http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/local-area-analysis-of-qualifications-across-england-and-wales/index.html (accessed: 26/03/2016).

22. The Scottish Government. Scotland's Census www.gov.scot (accessed: 26/03/2016).

23. Wang Y, Hunt K, Nazareth I, Freemantle N, Petersen I. Do men consult less than women? An analysis of routinely collected UK general practice data. *BMJ Open* 2013;**3**: e003320, doi:10.1136/bmjopen-2013-003320.

24. National Cancer Institute SEER Cancer Statistics Review 1975-2012 http://seer.cancer.gov/csr/1975_2012/browse_csr.php?sectionSEL=16&pageSEL=sect_16_table.05.html (accessed: 19/03/2016).

25. Jackson A, Wilkinson C, Ranger M, Pill R, August P. Can primary prevention or selective screening for melanoma be more precisely targeted through general practice? A prospective study to validate a self administered risk score. *BMJ* 1998;**316**: 34–38.

26. Mackie RM, Freudenberger T, Aitchison TC. Personal risk-factor chart for cutaneous melanoma. *Lancet* 1989;**2**: 487–490.

27. Noble NE, Paul CL, Carey ML, Sanson-Fisher RW, Blunden S V, Stewart JM, Conigrave KM. A cross-sectional survey assessing the acceptability and feasibility of self-report

electronic data collection about health risks from patients attending an Aboriginal Community Controlled Health Service. *BMC Med Inform Decis Mak* 2014;**14**: 34, doi:10.1186/1472-6947-14-34.

28. Martins T, Ukoumunne OC, Banks J, Raine R, Hamilton W. Ethnic differences in patients' preferences for prostate cancer investigation: a vignette-based survey in primary care. *Br J Gen Pract* 2015;**65**: e161–e170, doi:10.3399/bjgp15X683965.

29. Banks J, Hollinghurst S, Bigwood L, Peters TJ, Walter FM, Hamilton W. Preferences for cancer investigation: a vignette-based study of primary-care attendees. *Lancet Oncol* 2014;**2045**: 1–9, doi:10.1016/S1470-2045(13)70588-6.

30. Walter FM, Abel GA, Lyratzopoulos G, Melia J, Greenberg D, Brewster DH, Butler H, Corrie PG, Campbell C. Seasonal variation in diagnosis of invasive cutaneous melanoma in Eastern England and Scotland. *Cancer Epidemiol* 2015;**39**: 554–561, doi:10.1016/j.canep.2015.06.006.

31. National Institute for Health and Care Excellence (2015) Melanoma: assessment and management of melanoma (Draft for consultation) https://www.nice.org.uk/guidance/gid-cgwave0674/documents/melanoma-draft-nice-guideline2 (accessed: 26/03/2016).

32. Girgis A, Clarke P, Burton RC, Sanson-Fisher RW (1996) Screening for melanoma by primary health care physicians: a cost-effectiveness analysis. *J Med Screen* **3**: 47–53.

33. Sherwin HN, McKeown M, Evans MF, Bhattacharyya OK (2013) The waiting room 'wait': from annoyance to opportunity. *Can Fam Physician* **59**: 479–481.

TITLES AND LEGENDS TO FIGURES

Figure 1. Recruitment flow chart

Figure 2. Distribution of risk scores. Vertical lines mark the four different score cut-offs (25, 28, 30 and 34) of the Williams model (20) melanoma risk score with the percentage of participants above each threshold alongside.

Box 1: Williams model melanoma risk score calculation (range 0-67) (20)

Risk factor	Score	Risk factor	Score
Sex		Prior non-melanoma skin cancer	
Male	7	No	0
Female	0	Yes	13
Age in years		Number of raised moles on both arms	
35-44	0	None	0
45-54	5	1	3
55-64	8	2	5
65-74	11	3 or more	11
Natural hair colour at age 15		Density of freckles on arms before age 20	
Dark brown/black	0	None	0
Light brown	4	A few	4
Blond	5	Several	6
Red	8	A lot	10
Number of severe sunburns aged 2-18			
None	0		
1-4	1		
5-9	4		
10 or more	7		

Table 1: Characteristics of General Practices

	Practice type	Practice population[a]	Cancer prevalence[b]	Deprivation (IMD quintile)[c]	Number recruited
Eastern England					
	Urban	20,279	2.1	3	422
	Urban	17,657	2.8	2	392
	Urban	11,396	3.0	3	395
	Rural	11,129	2.1	1	436
	Rural	10,517	1.8	1	300
	Rural	10,408	2.1	2	396
	Urban	9,549	2.2	1	433
	Urban	9,115	2.2	2	458
	Urban	8,372	2.4	3	396
	Urban	4,229	2.7	4	409
North East Scotland					
	Semi-rural	20,976	2.1	2	431
	Semi-rural	15,726	2.2	3	326
	Semi-rural	12,222	2.8	1	150
	Urban	11,062	1.9	5	368
	Rural	6,179	2.4	2	122
	Rural	1,845	1.6	1	83
North Wales					
	Semi urban	15,409	2.4	2	387
	Urban	13,068	2.4	3	384
	Urban	9,935	2.8	4	195
	Rural	8,331	2.8	2	502
	Semi urban	7,552	0.6	4	236
	Semi urban	5,801	2.2	2	342

[a] At time of recruitment
[b] Prevalence data in the Quality and Outcomes Framework: percentage of patients with a diagnosis of cancer, excluding non-melanotic skin cancer. England and Wales 2013-2014 from www.gpcontract.co.uk and Scotland 2012-2013 from www.isdscotland.org.qof
[c] Index of Multiple Deprivation (IMD) quintiles computed using the practice postcode and published values for IMD where 1 is the least deprived.

Table 2: Sociodemographic characteristics of participants

Characteristic	Eastern England *n* (%)	Northeast Scotland *n* (%)	North Wales *n* (%)	Total *n* (%)	Population > 20 years registered at all practices *n* (%)
Gender					
Male	1399 (34.6)	517 (34.9)	775 (37.9)	2691 (35.6)	91,593 (49.5)
Female	2641 (65.4)	963 (65.1)	1271 (62.1)	4875 (64.4)	93,560 (50.5)
Age in years					
20-35 years	916 (22.7)	298 (20.1)	567 (27.7)	1781 (23.5)	43,286 (23.4)
35-44 years	692 (17.1)	218 (14.7)	335 (16.3)	1245 (16.5)	32,500 (17.5)
45-54 years	671 (16.6)	238 (16.1)	351 (17.2)	1260 (16.7)	35,804 (19.3)
55-64 years	611 (15.1)	264 (17.8)	325 (15.9)	1200 (15.9)	29,245 (15.8)
65-74 years	630 (15.6)	260 (17.6)	317 (15.5)	1207 (16.0)	24,374 (13.2)
≥75 years	520 (12.9)	202 (13.6)	151 (7.4)	873 (11.5)	19,944 (10.8)
Ethnic group					
White British	3620 (89.6)	1372 (92.7)	1945 (95.1)	6937 (91.7)	---
White other	224 (5.5)	75 (5.1)	63 (3.1)	362 (4.8)	---
Mixed	27 (0.7)	9 (6.1)	5 (0.2)	41 (0.5)	---
Asian or Asian British	87 (2.2)	9 (6.1)	12 (0.6)	108 (1.4)	---
Black or Black British	35 (0.9)	5 (0.3)	7 (0.3)	47 (0.6)	---
Chinese	12 (0.3)	2 (0.1)	5 (0.2)	19 (0.3)	---
Other ethnic group	35 (0.8)	8 (0.5)	9 (0.4)	52 (0.7)	---
Education					
None	719 (17.8)	295 (19.9)	349 (17.1)	1363 (18.0)	---
GCSE, O Level or CSE	975 (24.1)	285 (19.2)	528 (25.8)	1788 (23.6)	---
Vocational	684 (16.9)	293 (19.8)	387 (18.9)	1364 (18.0)	---
A Level or equivalent	570 (14.1)	162 (10.9)	271 (13.2)	1003 (13.3)	---
Undergraduate degree	386 (9.6)	190 (12.8)	210 (10.3)	786 (10.4)	---
Postgraduate degree or professional qualification	706 (17.5)	255 (17.2)	301 (14.7)	1262 (16.7)	---
Employment status					
Retired	1276 (31.6)	481 (32.5)	517 (25.3)	2274 (30.1)	---
Unemployed, seeking work	99 (2.5)	29 (2.0)	63 (3.1)	191 (2.5)	---
Unemployed, unable to work	63 (1.6)	23 (1.6)	72 (3.5)	158 (2.1)	---
Student	67 (1.7)	54 (3.6)	64 (3.1)	185 (2.4)	---
Working part-time	778 (19.3)	288 (19.5)	331 (16.2)	1397 (18.5)	---
Working full-time	1393 (34.5)	472 (31.9)	849 (41.5)	2714 (35.9)	---
Home Carer/Homemaker	308 (7.6)	97 (6.6)	100 (4.9)	505 (6.7)	---
Permanently sick or disabled	56 (1.2)	36 (2.4)	50 (2.4)	142 (1.9)	---

Table 3. Risk factor profile of participants

Risk factor	Point score	Eastern England *n* (%)	Northeast Scotland *n* (%)	North Wales *n* (%)	All *n* (%)
Sex					
Male	7	1399 (34.6)	517 (34.9)	775 (37.9)	2691 (35.6)
Female	0	2641 (65.4)	963 (65.1)	1271 (62.1)	4875 (64.4)
Age in years					
<44	0	1608 (39.8)	516 (34.8)	902 (44.0)	3026 (40.0)
45-54	5	671 (16.6)	238 (16.1)	351 (17.2)	1260 (16.7)
55-64	8	611 (15.1)	264 (17.8)	325 (15.9)	1200 (15.9)
>65	11	1150 (28.5)	462 (31.2)	468 (22.9)	2080 (27.5)
Natural hair colour at age 15					
Dark brown/black	0	1,518 (37.6)	579 (39.1)	811 (39.6)	2,908 (38.4)
Light brown	4	1,634 (40.4)	574 (38.8)	830 (40.6)	3,038 (40.2)
Blond	5	718 (17.8)	230 (15.5)	306 (15.0)	1,254 (16.6)
Red	8	170 (4.2)	97 (6.6)	99 (4.8)	366 (4.8)
Number of severe sunburns aged 2-18					
None	0	2,111 (52.2)	698 (47.2)	892 (43.6)	3,701 (48.9)
1-4	1	1,623 (40.2)	609 (41.1)	964 (47.1)	3,196 (42.2)
5-9	4	197 (4.9)	94 (6.4)	121 (5.9)	412 (5.5)
10 or more	7	109 (2.7)	79 (5.3)	69 (3.4)	257 (3.4)
Prior non-melanoma skin cancer					
No	0	3,930 (97.3)	1,457 (98.4)	1,996 (97.6)	7,383 (97.6)
Yes	13	110 (2.7)	23 (1.6)	50 (2.4)	183 (2.4)
Number of raised moles on both arms					
None	0	2,654 (65.7)	1,020 (68.9)	1,298 (63.4)	4,972 (65.7)
1	3	618 (15.3)	163 (11.0)	279 (13.6)	1,060 (14.0)
2	5	312 (7.7)	123 (8.3)	202 (9.9)	637 (8.4)
3 or more	11	456 (11.3)	174 (11.8)	267 (13.1)	897 (11.9)
Density of freckles on arms before age 20					
None	0	1,793 (44.4)	591 (40.0)	707 (34.6)	3.091 (40.9)
A few	4	1,309 (32.4)	481 (32.5)	792 (38.7)	2,582 (34.1)
Several	6	518 (12.8)	159 (10.7)	261 (12.7)	938 (12.4)
A lot	10	420 (10.4)	249 (16.8)	286 (14.0)	955 (12.6)
Total score (mean (sd))		16.8 (8.5)	17.9 (8.4)	17.4 (8.6)	17.1 (8.5)

Table 4: The population above various risk score cut-offs of the Williams model melanoma risk score (20) along with the estimated positive predictive and negative predictive values

Region	Williams' Risk score cut-off	Sample above cut-off (%)	Practice population above cut-off (%)[a]	Estimated 5-yr PPV (%)[b]	Estimated 5-yr NPV (%)[c]
Eastern England	25	16.5	17.7	3.1	99.5
	28	10.3	11.0	3.4	99.4
	30	7.4	7.9	4.3	99.3
	34	3.1	3.5	5.7	99.2
Northeast Scotland	25	20.8	22.4	3.4	99.4
	28	12.7	12.9	3.7	99.3
	30	9.6	9.8	4.7	99.3
	34	3.2	3.6	6.2	99.1
North Wales	25	18.5	19.3	3.7	99.4
	28	11.3	12.2	3.9	99.3
	30	8.1	8.5	4.8	99.2
	34	3.7	4.9	6.3	99.1
All	25	17.9	19.4	---	---
	28	11.0	11.8	---	---
	30	8.0	8.6	---	---
	34	3.9	3.9	---	---

[a] Weighted for the age and gender of the registered population in each participating practice

[b] Estimated 5-yr PPV – the estimated proportion of the population considered higher risk who would be diagnosed with melanoma in the next 5 years, assuming the same performance of the Williams model as reported in Williams *et al* 2011 and a prevalence of newly diagnosed cases of 104.5/100,000 for England (the 2011 crude incidence of melanoma in England from data from the Office of National Statistics multiplied by 5), 119/100,000 for Wales (the 2011 crude incidence of melanoma in Wales from the Welsh Cancer Intelligence and Surveillance Unit) and 114.5/100,000 for Scotland (the 2011 crude incidence of melanoma in Scotland from the Cancer Information Programme, Information Services Division Scotland)

[c] Estimated 5-yr NPV - the estimated proportion of the population considered low risk who would not be diagnosed with melanoma in the next 5 years, assuming the same performance of the Williams model as reported in Williams *et al* 2011 and a prevalence of newly diagnosed cases of 104.5/100,000 for England (the 2011 crude incidence of melanoma in England from data from the Office of National Statistics multiplied by 5), 119/100,000 for Wales (the 2011 crude of melanoma in Wales from the Welsh Cancer Intelligence and Surveillance Unit) and 114.5/100,000 for Scotland (the 2011 crude incidence of melanoma in Scotland from the Cancer Information Programme, Information Services Division Scotland)